Minimum sampling area and α biodiversity of riparian broad-leaved/Korean pine forest in Erdaobaihe forested watershed, Changbai Mountain

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Abstract: Riparian zone is an important component of forested watershed. Species component, structure, and distribution pattern of plant community in riparian zone are different from those of forest far away from the riparian zone because of edge effect and influence of river, and their minimum sampling areas are also different. To study the minimum area and α biodiversity of broad-leaved/Korean pine forest in riparian zone, three 8 m × 32 m sampling belts were selected and distributed at elevation of 800 m, 900 m, and 1 000 m. In the riparian broad-leaved/Korean pine forest, mean minimum sampling areas including 60%, 80%, and 90% of total species were 80 m^2 (8 m×10 m), 180 m^2 (12 m×15 m), and 320 m^2 (16 m × 20 m) respectively; The corresponding mean minimum areas of non-riparian forest were about 260 m^2, 380 m^2, and 480 m^2; and the former were smaller than the latter. In the riparian zone, species richness, Shannon-Weiner index and species evenness were also higher than those in non-riparian forest. On the contrary, species dominance in forest community was higher than that in riparian zone.

Keywords: Riparian zone; Species-area curve; Minimum sampling area; α biodiversity; Species richness; Species evenness; Broad-leaved/Korean pine forest; Forested watershed
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Introduction

Riparian zone is a kind of landscape, which is represented as aquatic-terrestrial ecotone. Management of streams, lakes, and wetlands in forest ecosystems represents one of the most revolutionary changes in forestry in the latter half of the 20th century (Gregory 1997), and along with the continuous development of studies on stream ecosystems (Cummins 1974; Vannote *et al.* 1980; Minshall *et al.* 1985) and watershed ecology (Cai *et al.* 1997; Deng *et al.* 1998), the combination of terrestrial ecosystems and aquatic ecosystems researches is a new current in ecosystem studying. Therefore, more ecologists pay their attentions to riparian zone and are aware of the important effects of riparian zone in basic study and practical management (Deng *et al.* 2001a). As a kind of ecotone and intensely influenced by river, riparian zone is different in species, structure, and pattern from non-riparian plant vegetation. The previous studies on plant communities often focused on the non-riparian plant vegetation, and there are few relative studies on riparian vegetation in China (Jiang *et al.* 2000).

Studies on minimum sampling area, species richness, and species evenness are the basic tasks in the structure and function of riparian forest or vegetation. Minimum sampling area, namely critical sampling area, means the minimum area in which species components can be acquired sufficiently (Wang *et al.* 1996), and reflects the inhere characteristics of vegetation. Minimum sampling area lies on vegetation type to a great extent and varies in a wide range. Determining minimum sampling area is the chief step to study plant communities, especially obtain field data quantificationally. Generally, α biodiversity can be classified into three types as richness index, biodiversity index, and evenness index. Species richness often means number of species in a certain plant community or habitat, and it is a most basic conception of biodiversity with a long history. Poole (1974) pointed out that only species richness was an objective index of biodiversity. So, species richness is usually used to study α biodiversity (Liu *et al.* 1997).

There are a lot of studies on vegetation but few studies on riparian vegetation carried out in Changbai Mountain. So, in this study, minimum sampling area and α biodiversity (species richness, Shannon-Weiner index, and species evenness) were investigated and discussed to comprehend the structural characteristics of riparian vegetation and provide a scientific guidance of riparian management.

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Study sites and methods

Study areas

This study site of the broad-leaved/Korean pine forest was located between latitude 41º31'-42º28'N and longitude 127º09'-128º55'E, on the north slope of Changbai Mountain and in the riparian zone of Erdaobaihe River (Deng *et al.* 2000; 2001b). Erdaobaihe River originates from Sky Lake, a volcanic lake on the top of Changbai Mountain, and it is the upriver source of Songhua River. From the peak to the piedmont, Erdaobaihe River passes through all the different vegetation belts on the north slope of Changbai Mountain. Broad-leaved/Korean pine forest, which is distributed below the elevation of 1 100 m above sea level, is one of the vegetation belts. The chief tree species of virgin broad-leaved/Korean pine forest are Korean pine (*Pinus koraiensis*), *Tilia amurensis*, *T. mandshurica*, *Quercus mongolica*, *Fraxinus mondshires*, and *Acer mono* (Deng *et al.* 2000). There are also *Larix olgensis*, *Abies nephrolepis*, *Ulmus japonica*, *U. laciniata*, *Populus ussuriensis*, *P. davidiana*, *Betula platyphylla*, and *B. costata* with different quantities in the existent forest because of different disturbances.

Sampling

Three sampling belts, which were vertical to river bank and distributed at 800 m, 900 m, and 1 000 m, respectively, were selected to investigate the riparian vegetation, and the area of each sampling belts was 8 m×96 m. Area of all the quadrats in the sampling belts was 4 m×4 m, and in the front of the river for 20 m, each 4 m×4 m quadrat was divided into four small quadrats for each 2 m×2 m quadrat. Therefore, there were forty-eight 4 m×4 m quadrats in total and forty 2 m×2 m quadrats at each elevation. From 800 m to 1 000 m at the elevation, the width of Erdaobaihe River varies in a range of 20-30 m, and the mean width is about 26 m.

Investigation

In the summer of 2000, altitude, slope degree, and coverage of the quadrats were investigated, and a sketch map of each belt was drawn. In each quadrat, the species of herbs and shrubs, abundance, coverage, and average height of trees were investigated, and species, diameter, and height of trees were investigated.

Minimum sampling area

There are several methods (Wang *et al.* 1996; Deng *et al.* 1999) to determine minimum sampling area such as species-area curve, important value-area curve, and community coefficient-area curve. Among them, species-area curve was applied widely because of its convenience, and this method was also used to determine the minimum sampling area of riparian broad-leaved/Korean pine forest in this study. Two equations (Liu *et al.* 1998; Deng *et al.* 1999) were used to simulate the species-area curves.

$$S = \frac{aA}{1+bA} \quad (1)$$

$$S = \frac{c}{1+ae^{-bA}} \quad (2)$$

Where, A is area (m^2), S is number of species, and a, b, and c are parameters. Software SYSTAT (Wilkinson 1990) was used to do the simulating.

Corresponding to the equations, minimum sampling area containing a certain proportion p ($0<p<1$) of all species could be determined as follows (de Caprariis *et al.* 1976; Liu *et al.* 1998):

$$A = \frac{p}{b(1-p)} \quad (3)$$

$$A = -\frac{\ln\left(\frac{1-p}{ap}\right)}{b} \quad (4)$$

Species richness, evenness, Shannon-Weiner index, and dominance

The sampling belts of 8 m×96 m were divided into three segments (8 m×32 m) at the distance of 0-32 m, 32-64 m, and 64-96 m from the river bank, and the structure was distinguished as tree layer (TL), shrub layer (SL), herb layer (HL), and total species (TS). And quantities of each species were calculated, and Shannon-Weiner biodiversity index (H), species evenness (E), and dominance index (D) were analyzed (Peng 1987; Wang *et al.* 1996).

$$H = -\sum_{i=1}^{s} V_i \ln V_i \quad (5)$$

$$E = H/\ln S \quad (6)$$

$$D = \sum_{i=1}^{s} V_i^2 \quad (7)$$

Where, V_i is relative importance value of species i.

Results

According to the corresponding data of area and species number, the simulated equations were gained and the results were shown in Table 1. In the simulated equations, the number of samples was 17, values of R^2 were higher than 0.92, and values of corrected R^2 (Wilkinson 1990) were higher than 0.77.

Table 1. The modeling results of species-area curves

Elevation /m	Layer	Equation	Parameter			R^2	Corrected R^2
			a	*b*	*c*		
800	Tree layer	1	1.008	0.042		0.995	0.954
800	Tree layer	2	2.291	0.019	23.997	0.998	0.980
800	Shrub layer	1	0.558	0.018		0.997	0.983
800	Shrub layer	2	4.190	0.017	30.899	0.979	0.879
800	Herb layer	1	1.080	0.030		0.995	0.953
800	Herb layer	2	1.840	0.011	35.788	0.923	0.992
800	Total species	1	2.457	0.027		0.998	0.984
800	Total species	2	2.637	0.016	90.567	0.992	0.934
900	Tree layer	1	0.525	0.021		0.982	0.813
900	Tree layer	2	1.550	0.006	24.874	0.993	0.928
900	Shrub layer	1	0.324	0.012		0.985	0.913
900	Shrub layer	2	3.043	0.007	26.698	0.996	0.976
900	Herb layer	1	1.632	0.032		0.996	0.960
900	Herb layer	2	1.950	0.013	50.543	0.992	0.925
900	Total species	1	2.266	0.022		0.991	0.925
900	Total species	2	1.900	0.008	101.882	0.993	0.942
1 000	Tree layer	1	1.518	0.069		0.987	0.770
1 000	Tree layer	2	1.082	0.010	21.991	0.998	0.973
1 000	Shrub layer	1	0.600	0.030		0.995	0.955
1 000	Shrub layer	2	2.584	0.017	19.897	0.994	0.949
1 000	Herb layer	1	1.159	0.019		0.990	0.914
1 000	Herb layer	2	2.003	0.008	60.156	0.995	0.961
1 000	Total species	1	2.678	0.026		0.991	0.907
1 000	Total species	2	1.814	0.009	102.776	0.997	0.968

While the values of proportion *p* were 0.6, 0.8, and 0.9, according to equations (3) and (4), the minimum sampling areas of communities and different layers were calculated, and the results were shown in Table 2. In the riparian forest, while value of proportion *p* was 0.6, the mean critical sampling areas of tree layer, shrub layer, herb layer, and all species in communities were 64 m^2, 111 m^2, 81 m^2, and 85 m^2, and the area of 80 m^2 (8 m×10 m) of them was the suitable sampling area. While value of proportion *p* was 0.8, the mean critical sampling areas of tree layer, shrub layer, herb layer, and all species in communities were 152 m^2, 225 m^2, 178 m^2, and 184 m^2, and the suitable sampling area was 180 m^2 (12 m×15 m). While value of proportion *p* was 0.9, the mean critical sampling areas of tree layer, shrub layer, herb layer, and all species in communities were 267 m^2, 404 m^2, 315 m^2, and 325 m^2, and the suitable sampling area was 320 m^2 (16 m×20 m).

Table 2. Minimum sampling area (m^2) of communities and different layers with different *p*-values

Elevation/m	Equation	*p*= 0.6				*p* = 0.8				*p* = 0.9			
		TL	SL	HL	TS	TL	SL	HL	TS	TL	SL	HL	TS
800	1	36	83	50	56	95	222	133	148	214	500	300	333
800	2	65	108	92	86	117	166	181	147	159	214	255	198
900	1	71	125	47	68	190	333	125	182	429	750	281	409
900	2	141	217	83	131	304	357	158	254	439	473	220	355
1 000	1	22	50	79	58	58	133	211	154	130	300	474	346
1 000	2	48	80	138	111	147	137	260	220	228	185	361	310

Notes: TL--- tree layer; SL--- shrub layer; HL--- herb layer; TS--- total species.

Compared with three 32 m×32 m quadrats in the forest communities far away from the riparian zone at elevation of 800 m, 900 m, and 1 000 m respectively, while value of proportion *p* was 0.6, the corresponding mean critical sampling areas were 197 m^2, 205 m^2, 367 m^2, and 275 m^2, while value of proportion *p* was 0.8, the corresponding mean critical sampling areas were 280 m^2, 292 m^2, 522 m^2, and 390 m^2, and while value of proportion *p* was 0.9, the corresponding mean critical sampling areas were 368 m^2, 386 m^2, 689 m^2, and 514 m^2 (Hao 2000). So, the minimum sampling area of riparian community was smaller than that of forest community, which was correlative with the special

habitat and plant distribution pattern in riparian zone closely.

From Table 3, the results showed that numbers of species of different layers at different elevations in riparian zone were more than those in forest, except number of herb species at elevation of 800 m. There existed more abundant species in riparian zone, despite the sampling area in riparian zone was less than that in forest. Shannon-Wiener index in table 4 also confirmed this result. For different segments in the riparian sampling belt, species number in the segment (0-32 m) nearest to the river was obviously higher than that in other segments (32-64 m, 64-96 m), and species numbers in other segments were similar. It was shown that, in the riparian sampling belt, more species distributed in the segment near the river, and species richness was higher in riparian zone. Table 4 also showed that evenness of plant species in riparian zone was higher than that in forest community because of special habitat. In the riparian zone, there existed abundant species, and distribution of the species was even comparatively. In the forest community far away from the river, there existed less species, and the species distributed concentrically. On the contrary, species dominance in forest community was higher than that in riparian zone.

Table 3. Species richness in different segments of sampling belt compared with that in non-riparian forest quadrat

Elevation/m	Layer	Number of species in riparian zone				Number of species in
		0-32 m	32-64 m	64-96 m	Total	non-riparian forest quadrat
800	Tree layer	24	18	18	24	20
800	Shrub layer	25	20	20	31	15
800	Herb layer	30	24	20	36	42
800	Total species	79	62	58	91	77
900	Tree layer	17	16	15	25	14
900	Shrub layer	19	17	13	27	15
900	Herb layer	44	30	31	51	32
900	Total species	80	63	59	103	61
1 000	Tree layer	21	12	13	22	17
1 000	Shrub layer	19	15	15	20	14
1 000	Herb layer	49	40	43	61	45
1 000	Total species	89	67	71	103	76

Table 4. Comparison of species evenness (*E*), dominance (*D*), and biodiversity (*H*) in riparian sampling belt and in non-riparian forest quadrat

Elevation/m	Layer	Riparian belt (8 m×96 m)			Non-riparian forest quadrat (32 m×32 m)		
		E	*D*	*H*	*E*	*D*	*H*
800	Tree layer	0.824	0.095	2.618	0.812	0.113	2.432
800	Shrub layer	0.910	0.059	3.126	0.864	0.130	2.340
800	Herb layer	0.853	0.082	3.056	0.938	0.036	3.508
900	Tree layer	0.790	0.110	2.542	0.744	0.185	1.965
900	Shrub layer	0.903	0.064	2.975	0.903	0.105	2.444
900	Herb layer	0.930	0.033	3.656	0.873	0.087	3.027
1000	Tree layer	0.803	0.104	2.481	0.779	0.164	2.208
1000	Shrub layer	0.908	0.085	2.719	0.880	0.118	2.323
1000	Herb layer	0.947	0.025	3.895	0.919	0.042	3.500

Conclusions

In the riparian broad-leaved/Korean pine forest, mean minimum sampling areas including 60%, 80%, and 90% of total species were 80 m^2 (8 m×10 m), 180 m^2 (12 m×15 m), and 320 m^2 (16 m×20 m), respectively. The corresponding areas of forest were about 260 m^2, 380 m^2, and 480 m^2. The former were smaller than the latter, but species richness was higher in the riparian zone. In the riparian zone, besides species richness, Shannon-Weiner index and species evenness were also higher than those in forest far away from the riparian zone, species number in the segment (0-32 m) nearest to the river was obviously higher than that in other segments (32-64 m, 64-96 m), and species numbers in other segments were similar. On the contrary, species dominance in forest community was higher than that in riparian zone.

In common, form of sampling site will influence the result, and sampling belt or transect of same area will contain more species and reflect more variation of vegetation (Zheng *et al.* 1994; Wang *et al.* 1996). In this study, although sampling belt in riparian zone was compared to quadrat in forest, the results could confirm that species richness was higher in the riparian zone, because the area of sampling belt (8 m×96 m or 8 m×32 m) was smaller than

that of quadrat of forest area.

Minimum sampling areas of different layers was different. In riparian zone, minimum sampling area of shrub layer was the largest, and the order in turn was total species, herb layer, and tree layer. In forest, the order of minimum sampling area in turn was herb layers, total species, shrub layer, and tree layer. This difference perhaps was related to distribution patterns of different layer and to explain this difference exactly, and a further study should be done.

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